International Journal for Modern Trends in Science and Technology
Volume 10, Issue 11, pages 14-24.
ISSN: 2455-3778 online
Available online at: http://www.ijmtst.com/vol10issue11.html
DOI: https://doi.org/10.46501/IJMTST1011003

Benefits and Difficulties of Student-Generative Artificial Intelligence Collaboration in Programming Learning: An Empirical Case Study

Dr. B. Sujatha[1] | Pothula Nani Babu[2]

[1]Depaertment of Computer Science and Engineering, Godavari Global University, RJY
[2]Department of Computer Science and Engineering, Kakinada Institute of Engineering and Technology, Korangi

To Cite this Article
Dr. B. Sujatha and Pothula Nani Babu, Benefits and Difficulties of Student-Generative Artificial Intelligence Collaboration in Programming Learning: An Empirical Case Study, International Journal for Modern Trends in Science and Technology, 2024, 10(11), pages. 14-24. https://doi.org/10.46501/IJMTST1011003

Article Info
Received: 24 October 2024; Accepted: 14 November 2024.; Published: 18 November 2024.

ABSTRACT

Conversational generative artificial intelligence Gen AI is sometimes viewed as a two-edged sword that could result in learning that is only superficial. We created and implemented a programming course that emphasizes student-Gen AI collaboration. The dynamics of such collaboration are examined in this study, with particular attention paid to students' communication tactics with Gen AI, perceived advantages, and difficulties faced. Class observations, questionnaires, final reports, student-Gen AI conversations, and semi-structured in-depth interviews were all used to gather data. The findings demonstrated that productive student-Gen AI collaboration might improve students' self-regulated and metacognitive learning abilities as well as have a good effect on human-to-human communication. The challenges and individual variations in working with Gen AI on challenging learning tasks were also disclosed by this study. All things considered, working with Gen AI as a learning partner as opposed to merely a tool allows for autonomous and sustained learning that goes beyond certain learning assignments at a particular moment.

KEYWORDS: Conversational generative AI, student-AI cooperation, learning programming, metacognition, and self-regulated learning abilities.

1.INTRODUCTION

Conversational generative artificial intelligence (Gen AI) is showing up in many different industries and is becoming more common in society. Technologies that can perform on par with humans, like Chat-GPT from Open AI, are quickly gaining prominence. However, there are also risks associated with using Gen AI in education, despite its obvious advantages [1–3]. Deeper learning may be hindered and plagiarism may be a

problem when using Gen AI output in its current form as a learning artifact [4,5].

Students who rely too much on Gen AI face the danger of learning nothing at all or only superficially, and Gen AI output may contain biases or misleading information [6–9]. A Gen AI policy in education is therefore required since many colleges prohibit students from utilizing Gen AI in their coursework [10]. The use of Gen AI in education is still up for dispute, especially regarding its complete acceptance. We have discovered a substantial potential for these technologies to promote active learning and self-regulated learning through improved communication and collaboration between learners and Gen AI as a result of our year-long engagement with a variety of Gen AI platforms, including ChatGPT-3.5, ChatGPT-4, Bing AI, and Claude2. Gen AI sets itself apart from its forebears by promoting greater understanding, a richer exchange of ideas, and more nuanced and effective communication [11]. This development solves the issues that traditional AI had in the past when it came to building productive working connections with pupils [12]. But in the beginning, it would be challenging for pupils to develop efficient communication with Gen AI because of an Educ. ignorant of the difference between human and AI communication.

As a result, a large number of blogs and videos offer helpful communication hints with Gen AI.In this empirical case study, we created a programming course for beginning students to learn how to collaborate and communicate effectively with Gen AI (ChatGPT, Bing AI) through programming activities. We then discussed the advantages and difficulties of this approach based on four research questions:

Research Question 1 (RQ1) is: What do students think about the way they communicate with Gen AI?

Research Question 2 (RQ2) How do students build their cooperation with Gen AI in concept learning and app development?

Research Question 3 (RQ3): How do students assess the use of Gen AI in their education?

Research Question 4 (RQ4): What kinds of difficulties do students encounter when working together?

Collaboration between Students and AI:

In order to obtain better, more effective learning, students can develop active and reciprocal relationships with AI through a type of connection known as student–AI cooperation [12–14]. Instead of passively absorbing the knowledge from AI, students actively participate in the ongoing interaction with AI during student-AI collaboration, while the AI gathers and evaluates student data to accurately determine the students' learning level [12,15]. The main obstacle to students and AI developing a cooperative connection before the introduction of Gen AI was AI's incapacity to deliver reliable and efficient interaction [12]. Consequently, there was a lack of widespread discussion and clarity regarding the collaborative relationships between students and AI.

However, studies on students' collaborative learning offer a wealth of information. The constructivism theory of Vygotsky and Piaget serves as the foundation for both student-student collaborative learning and student-AI collaborative partnerships [12,20,22]. Higher education frequently uses collaborative learning, which is students actively participating in their education through conversations with others, frequently in small groups [22]. Collaborative learning, as a student-centered pedagogical method, is predicated on the idea that knowledge is created by students via productive interactions rather than only being imparted by instructors [20,21]. Additionally, the traits of collaborative learning include positive interdependence, equal partnerships, individual accountability, maximal peer contacts, and shared learning objectives [21, 23–25]. The concept of maximum peer engagement highlights the importance of student interactions in terms of both quantity and quality [24]. The goals of equal partnerships, personal responsibility, and constructive interdependence are to lessen dependency on educators and other group members and steer clear of partnerships in which one side solely depends on or gains from the others [23–25]. Through their interrelated experiences, these shared values among group members help to resolve conflicts and create new common values and knowledge communities [23].

However, we believe that student-Gen AI collaboration should not be oversimplified because, unlike human collaborators, Gen AI may exhibit either excessively active or passive patterns within the collaboration. Additionally, because Gen AI is dependent on student initiation—remaining inactive until prompted by questions—it may dominate interactions, making it difficult for students to foster an

equal partnership. As a result, students should consciously exert initiative and lead the establishment of learning objectives, strategies, and evaluations when engaging with Gen AI. Students must maintain a high degree of independence in order to ensure that they maintain ownership of their learning experience without it being overshadowed.

The Impact of Gen AI on Student Programming Education: In terms of writing, programming, and tests, ChatGPT made its debut in November 2022 as the top-performing AI chatbot ever; it gets better with every update. Notwithstanding the difficulties and dangers to education, integrating Gen AI into higher education is crucial for improving individualized instruction, preparing graduates for future societal roles, and providing them with Gen AI competency for a variety of industries [10]. The useful effects of Gen AI on student learning have been the subject of an expanding corpus of study [27, 28]. Through its conversational language skills, Gen AI can bridge the gap between non-programmers and the programming community, which holds enormous promise for helping students learn programming [29–32].

Gen AI makes use of machine learning and natural language processing technologies, in contrast to traditional programming resources, which are usually concentrated on particular programming languages or environments and frequently call for a basic understanding of programming ideas. This makes programming more approachable for people without programming experience by allowing it to comprehend and reply to user inquiries in natural language [29]. The potential of Gen AI technologies to improve programming education has been the subject of numerous research. Yilamz and Karaoglan Yilmaz [30] looked into how college students felt about studying programming with the Gen AI tool. Data was gathered using open-ended inquiries and surveys through a case study that involved programming tasks spread over eight weeks. The results emphasized both advantages like fast responses, assistance with debugging, and the development of thinking skills as well as drawbacks like possible indolence, inaccurate responses, and a lack of programming environment. Furthermore, Yilamz and Karaoglan Yilmaz [33] and Sun et al. [31] investigated the incorporation of Gen AI into programming education using quasi-experimental designs that evaluated control and experimental groups.

They concentrated on a number of outcomes, such as student engagement, computational thinking, self-efficacy, and motivation. The first study measured the effects of Gen AI tools on computational thinking, programming confidence, and learning motivation using a combination of approaches and found notable improvements in these domains.The second study examined how college students' programming practices and performances were affected by ChatGPT-assisted programming versus conventional self-directed learning techniques.More frequent debugging and exchanges showed that ChatGPT improved student involvement, but as compared to more conventional approaches, it did not considerably enhance programming proficiency. Beyond its immediate effects, though, Gen AI can have more continuous and meaningful interactions with kids. Neither the generated discussions nor the interactions between students and Gen AI have been thoroughly examined or discussed in prior research. The efficacy of ChatGPT was investigated by Hartley et al. [32] in four learning domains: planning, feedback, programming tools, and instructional material.One of the key conclusions they highlight is that user proficiency is crucial to the effectiveness of Gen AI in education. As a result, it is essential to research and comprehend how students engage with AI while learning programming.

2. METHODOLOGY

Class Design:

Figure 1 depicts the whole class design. Each month, the class was divided into four 180-minute classes. Our objective in this course is to help students develop effective communication and teamwork skills with the Gen AI in order to comprehend and develop apps. The course material gets harder and harder. The instructor used hands-on examples to introduce Gen AI to the class in the first lesson. Having Gen AI solve real report problems in class, comprehending its operation, and investigating its application in their own lives and interests taught them how to interact with Gen AI and create compelling prompts. Working with Gen AI to comprehend challenging programming concepts and codes was the main goal of the second lesson.

Through a conversation with Gen AI, where they asked questions and received explanations, problem-solving techniques, and feedback on their responses, students autonomously improved their comprehension of challenging codes or concepts. Under their supervision, students worked with AI to develop a basic chatbot application in the third lesson. The lecturer gave an example of their own development method. Following the instructor's demonstration, the students developed a simple, barely functional app and then altered it to suit their own tastes. Students used Gen AI to create their own unique applications in the fourth lesson. They had to strike a balance between "execution" and "understanding" when developing their software. "Execution" required students to make sure the codes were functioning as intended, and "understanding" required them to comprehend each code and provide an explanation in their own words. Together with Gen AI, students might finish the app after all the lessons.

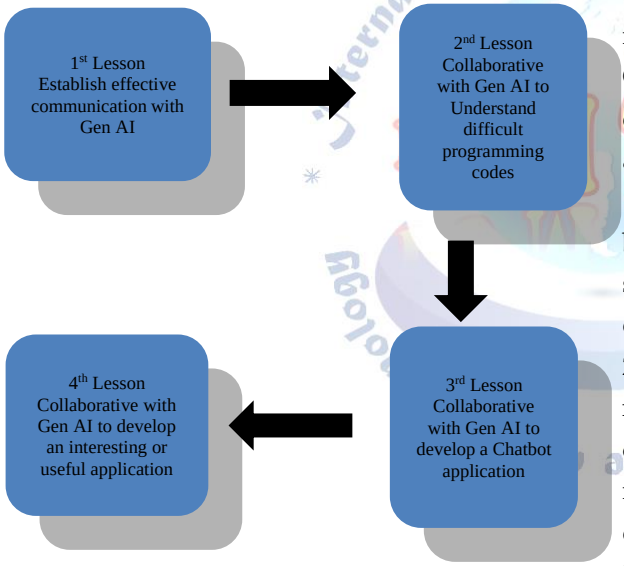

Figure 1. The class design.

The instructor used hands-on examples to introduce Gen AI to the class in the first lesson. Having Gen AI solve real report problems in class, comprehending its operation, and investigating its application in their own lives and interests taught them how to interact with Gen AI and create compelling prompts.

Working with Gen AI to comprehend challenging programming concepts and codes was the main goal of the second lesson. Through a conversation with Gen AI, where they asked questions and received explanations, problem-solving techniques, and feedback on their responses, students autonomously improved their comprehension of challenging codes or concepts. Under their supervision, students worked with AI to develop a basic chatbot application in the third lesson. The lecturer gave an example of their own development method. Following the instructor's demonstration, the students developed a simple, barely functional app and then altered it to suit their own tastes. Students used Gen AI to create their own unique applications in the fourth lesson. They had to strike a balance between "execution" and "understanding" when developing their software. "Execution" required students to make sure the codes were functioning as intended, and "understanding" required them to comprehend each code and provide an explanation in their own words. Together with Gen AI, students might finish the app after all the lessons.

Activities for Teaching and Learning:

1. Two main factors served as the foundation for the lessons. The main goal was to assist students in developing productive relationships with Gen AI. The instructor, who has six months of experience utilizing Gen AI to teach programming, articulated five key concepts for starting students while teaching them code and communication strategies:

Prompt management: to guarantee that learning was both contextual and progressive, the instructor assisted students in articulating their objectives, roles, and the context of their contact with Gen AI.

2. Memory management in Gen AI: it was suggested that new dialog threads be started at appropriate points in order to maintain Gen AI's contextual knowledge. This method reduces the possibility that lengthy conversations would result in less accurate responses.

3. Creating working code: It was advised to begin with a basic, functional code and progressively improve its features in order to increase the self-efficacy and motivation of inexperienced students. This approach creates a strong basis for future advancement.

4. Execution and comprehension: While the instructor recognized the value of Gen AI in code generation, she emphasized that in order to solve problems successfully, it is crucial to comprehend the created code. Finding a balance is essential since concentrating too much on comprehending every aspect can impede development.

5. Requesting feedback: it was emphasized how crucial it is to get Gen AI's input on programming and timely

management, which promotes a reflective learning process.

The second thing to think about was how to include the concepts of collaborative learning into the framework of student-Gen AI interaction. Instead of mainly depending on comprehensive instructional resources and procedures, the teacher promoted an environment where learning was driven by student engagement with Gen AI, emphasizing the value of student interdependence and individual accountability. Students were able to share their learning experiences and solutions through frequent group discussions, which promoted a collaborative learning environment. During these conversations, the instructor and teaching assistants offered advice and ideas to improve the educational process.

Participants of Classes:

The class consisted of nine students, all third-year undergraduates from the college of education at a prestigious Japanese university, who had all gained a foundational understanding of programming before enrolling in the class. This allowed for individualized support and comprehensive instruction for each student, as well as close monitoring of their learning progress.

Data Collection:

In order to examine how students learn and interact with Gen AI, this study used a thorough data collection methodology.

Observations in the classroom and questionnaire surveys:

Before and after classes, questionnaire surveys were given out, and observations of the classroom environment were used to collect data. In order to document how students' experiences and perspectives changed over time, these surveys were administered at six separate dates and included both descriptive questions and 5-point Likert scale items. They specifically sought to investigate how students interacted with Gen AI, what they learned, and how they felt about the course design and Gen AI. Refer to Appendix A for more information.

Completed Reports:

After all of the lessons and data were gathered, the students turned in their final reports. The following three issues were included in the final reports, which were used to compile the tactics students employed when developing collaboration with Gen AI and the learning results in programming learning: (1) How would you characterize your methods for working with Gen AI to understand concepts and codes? (2) How would you characterize your approaches to working with Gen AI to create an application? (3) Out of these four lessons, what are the most crucial learning objectives?

Documentation of Conversations with Gen AI:

Following the four lessons, all student records of their conversations with the Gen AI had to be turned in. These conversations were examined as information on student-Gen AI cooperation.

Interviews:

Three chosen students (Emma, Olivia, and Sophia) participated in in-depth, semi-structured interviews that lasted 40–60 minutes. The interviews yielded qualitative information about the students' learning experiences, class design, knowledge, attitudes toward Gen AI, and comparisons of Gen AI with real teachers.

Data analysis:

To examine documents and interview data, we employed qualitative content analysis [34]. Relevant information on RQ1–RQ4 was derived after multiple meticulous readings. After reading the transcripts several times, the first author created preliminary codes and developed preliminary themes through an inductive thematic analysis. Two coauthors then went over every transcript to carefully analyze the codes and find any discrepancies in interpretation. When there was dispute, the results and analytical procedure were discussed until an agreement was reached. Following data analysis, all data were translated from Japanese to English, and each translation was carefully examined to make sure there were no misconceptions.

3. RESULTS

What do students think about the way they communicate with Gen AI?

The information from the survey findings, final reports, and classroom observations was examined in order to respond to the first research question. As a result, as the

class went on, their communication style with Gen AI changed (Figure 2).

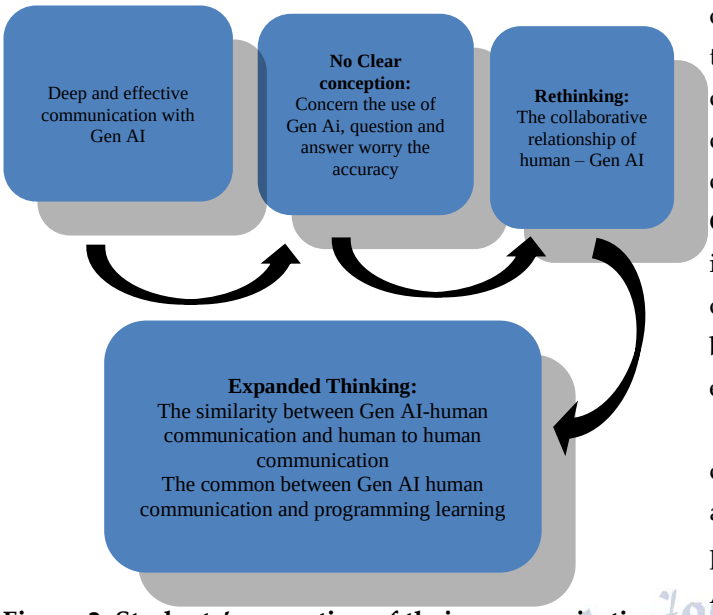

Figure 2. Students' perception of their communication with Gen AI.

Students' perceptions of Gen AI were unclear at the start of the course, but as it went on, their communication styles evolved.

According to the preliminary poll that was done prior to the first class, students were worried about how to use Gen AI since they thought of it as a simple information source like Siri or OK Google. But as the course went on, the students started to learn how to interact with Gen AI in an efficient manner. They experimented with various forms of communication, such as question-and-answer sessions, articulating clear and reasonable statements, thinking through responses from Gen AI, and using Gen AI to validate and clarify their ideas. An illustration of the kind of communication a student might use is provided below:

1. Clearly articulate my stance and the goal I have for Gen AI. I start by outlining my actual goals for Gen AI, after which I provide more specific details in bullet points.
2. If Gen AI's replies don't match my own, I clarify my intentions exactly and ask inquiries about the parts of the responses that I don't understand.
3. After I comprehend, I ask Gen AI to assess my work in light of my new knowledge. By doing this, I provide Gen AI explicit instructions on the evaluation standards it will employ.
4. Make the necessary revisions and have Gen AI review it. Until Gen AI responds, "good," I'll keep saying this.

In addition to learning how to communicate with Gen AI, the students started to consider and analyze their own learning preferences. They started considering how to set up Gen AI to support their learning in light of their concerns, like their inability to assess the veracity of the data they were giving it. In reference to this, a student commented as follows: "I heard some people in the ChatGPT review claim that it provides incorrect or inappropriate answers, but I thought that this depends on how we use it. I believed that at this point, it should be viewed more as a companion than an all-knowing entity that provides answers to arbitrary queries.

Additionally, one student said that developing his communication skills with Gen AI improved his logical and structural thinking, which is essential for learning programming.

Additionally, interacting with Gen AI enhanced students' technical, analytical, and expressive abilities. Students realized that precise information delivery is advantageous for both human-to-human conversation and Gen AI. Here are two students' comments:

"I discovered that, depending on my ability to pose questions and arrange the environment, I may receive useful responses from Gen AI. In particular, it was successful to succinctly convey some conditions and my and Gen AI's positions. Writing a clear and straightforward statement was a learning experience in and of itself, therefore I thought the process of getting an answer was as significant.

How do students build their cooperation with Gen AI in concept learning and app development?

The information from final reports was examined in order to respond to the second research question. Students reported a wide range of their experiences working with Gen AI in code learning and app development in their final reports, which were based on their experiences both during and after the class (Table 1).

Table 1. the methods developed by students to work with Gen AI on app development and code learning.

Learning Task	Strategies
Understanding Codes or Concepts	Prior to contacting Gen AI for clarification on a difficult topic, I try to organize my own understanding. I also check the accuracy of the information and broaden my knowledge while talking with Gen AI. Finally, I

	think critically and analyze by paraphrasing the response from Gen AI in my own words.
App Development	Analyzing oneself before assigning duties Communicate with Gen AI to clarify the matter. Transitioning from basic to sophisticated tactics Instead of asking Gen AI to solve problems, work with it to develop solutions.

Students first identified a number of distinctions between asking Gen AI and asking professors. They said that because they were better equipped to gauge each student's level of learning, teachers could explain the concepts and codes to them. Students had to assess their own learning levels before approaching Gen AI for clarifications, and then they had to ask more succinctly and clearly. In certain instances, they probed more frequently to analyze Gen AI's answers. Students discussed a variety of ways to communicate with Gen AI more successfully in this context. Students attempted to examine their own perceptions of themselves before requesting that Gen AI explain the codes or concepts. One student, for instance, said the following:

Initially, I believe that issues that are challenging to comprehend independently can be categorized into two categories: "I don't understand X" and "I don't understand what I don't understand in the first place." I can identify the points I don't grasp and seek clarification on my own if they are obvious. To go from "I don't know what I don't know" to "I don't know what X is," I simply listen to the explanation and then, one by one, ask for further information if I'm unsure of what I don't know.

Students asked Gen AI to explain the codes in various ways and requested information sources in order to address the potential for bias or inaccurate information. "By asking Gen AI to provide real-life examples, I am able to consolidate not only my understanding of the concept I asked, but also other concepts connected to it, and I am able to expand my knowledge," said one student who wanted to increase their knowledge of the subject. Furthermore, students stressed the importance of evaluating the response and rephrasing it in their own terms to ensure they understood it, as opposed to simply accepting the explanation from Gen AI.One student said, for instance:

I can arrange my comprehension by rephrasing Gen AI's explanations in my own terms. During the paraphrasing process, I can ask Gen AI to expound on anything I find difficult to put into my own words. Students discussed a number of methods for identifying unknown codes, such as the product operating codes, in relation to application development. Some pupils, for instance, emphasized the advantages of making little progress. "I think it is very suitable for me to develop the application step by step," said one pupil. It would be quite challenging to comprehend all of the information and create functional scripts if I moved forward all at once since [Gen AI] might provide me with too much information at once.

How do students assess the use of Gen AI in their education?

The information gathered from the surveys and interviews was examined in order to respond to the third research question. Students' perceptions of Gen AI revealed that it offers numerous benefits to enhance their learning effectiveness and influence their methods of learning (Table 2).

Table 2. The advantages of Gen AI on students' learning

Advantages of Gen AI	Examples
The benefits of increasing learning effectiveness	Quick reaction Accessibility Individualized degrees of difficulty Promotion of inquiry Learning continuity Effective information collection
favourable effects on the method of learning	Variability in learning methods Combining input and output learning Learning programming in real time Encouragement of self-regulated learning and student interdependence

Table 2. The advantages of Gen AI on students' learning

Advantages of Gen AI:

Another significant benefit of Gen AI is that it allows students to ask even simple questions that are challenging to pose to teachers or instructors. Students specifically mentioned the following comments

regarding the ability to request that the AI learn at their own pace and adapt to different difficulty levels: "I can increase the frequency of questions until I understand, and it doesn't matter what time or space I ask in, and the Gen AI explains the function along with the code." Students praised the fact that Gen AI responded to their questions immediately and said that they felt it was beneficial for beginner learners, especially when understanding Python syntax, as they were able to ask questions as they went along:

"It was beneficial because I could request a change in difficulty level with Gen AI without hesitation, something I would have found difficult to communicate to a teacher."It was challenging for me to ask questions when I was learning from teachers if I forgot the prior lesson's material. But with Gen AI, I may ask inquiries at any time and repeatedly until my pointless queries are answered. Additionally, students placed a high importance on Gen AI's capacity to raise their performance. For instance, students claimed that with the help of Gen AI, they could develop code that operated at a minimal level even if they had little experience with fundamental coding. Students also valued the fact that conversations with Gen AI are recorded.

Effect on the Method of Learning:

We discovered that the collaborative interaction between students and Gen AI has a significant impact on how students learn, in addition to the convenience that Gen AI offers to student learning as previously discussed. These outcomes foster student autonomy in addition to increasing the variety of learning styles. Through interactions with Gen AI, which featured simultaneous information input and output, students presented their new learning techniques. The traditional approach of learning is to input information first, then practice and produce results to get a comprehension of it. This approach has been modified by the use of Gen AI, though, so that knowledge input and output are carried out concurrently while real-time programming is learned through practical experience. Additionally, students were quite appreciative of how helpful working with Gen AI was to their programming education. Their ability to establish their own learning objectives, rank the material they wished to learn, and assess the learning process independently was one of the main ways that the partnership with Gen AI enhanced their capacity for self-regulated learning. When using Gen AI to learn, I have to think about what I want to do, let it create the code to make it happen, and then see what features it employs. Gen AI learning is special, in my opinion, because it allows me to learn how to use the programming language after logically constructing my goals and a plan for accomplishing them using natural language.

What kinds of difficulties do students encounter when working together?

Data from questionnaire surveys, class observations, student-AI interaction logs, and interviews were examined in order to address the final research topics.

Collaboration Challenges with Gen AI in Complex Learning Tasks.

Because it calls for students to apply self-regulated learning abilities like goal-setting, learning new codes, modifying techniques, and identifying the reason behind a "error" with Gen AI, app development is more challenging than comprehending complex topics. The majority of students reported irritation and difficulty forming cooperative relationships in the questionnaire surveys for the third and fourth lessons. The students believed they lacked the knowledge to comprehend Gen AI's responses when they asked it to clarify its code or offer fixes for mistakes. As a result, they felt that they lacked fundamental programming skills and found it difficult to communicate with Gen AI. As one illustration, a student stated: With functions and conditional branching, I was able to comprehend what I was doing. I was still confused, though, when it came to the specifics of the functions and other, somewhat more complex things. Additionally, I had to rely entirely on Gen AI when a mistake was returned. Since I was unable to determine the source when the issue recurred, I felt that I had to study on my own. I believed that I had to learn things on my own. Overall, it was challenging for the students to suggest changes because they couldn't agree on anything with Gen AI. Therefore, it was challenging to find a balance between what they understood and what they could do, as Emma stated in the interview.

Consideration of Differences between Students:

Individual ability is another difficulty in student-Gen AI collaboration. Following every lecture, students were

asked to complete a questionnaire that asked them to rate their own proficiency in creating engaging prompts. The findings demonstrated that, despite all of the classes, two pupils were still unable to produce an adequate prompt. A student expressed his thoughts on this matter: "I believe that Gen AI is really good at giving people a lot of information. But in my opinion, how effectively it makes use of that potential depends largely on people's capacity for self-expression and rational cognition. Additionally, their conversation logs with Gen AI in app development also showed individual variances. Although there was occasional evidence of their comprehension, there was one pupil who was relying too much on AI. The majority of students showed mediocre proficiency in working with Gen AI and made an effort to actively engage with it in order to complete their app development and gain a deeper knowledge.

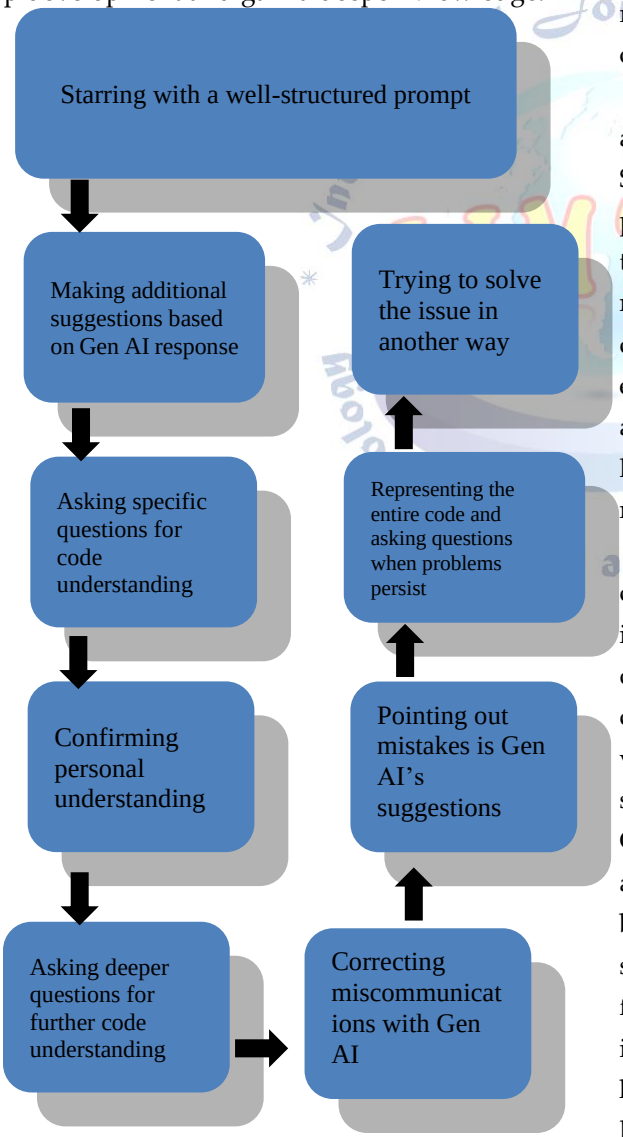

Figure 3. The student's approach to collaborating with Gen AI in app development

4. DISCUSSION AND CONCLUSIONS

In this case study, we created a programming course to teach students how to interact and collaborate with Gen AI in an efficient manner. We examined students' learning experiences and talked about how student-Gen AI collaboration affects learning using a variety of data collection methods. The advantages of student-Gen AI collaboration in student learning are demonstrated by the outcomes of RQ1–RQ3. However, the RQ4 results highlight the difficulties and individual variations in student-Gen AI cooperation. The findings of RQ1 demonstrate how students' attitudes toward and interactions with Gen AI have changed. Students who investigated ongoing and successful communication with Gen AI came to understand the significance of stating clearly, considering Gen AI's response critically, rephrasing it, and suitably assessing their learning outcomes.

The interaction between students and Gen AI changed as a result of this investigation. Students were usually the ones that received Gen AI prior to class, only evaluating how well AI worked as a teaching aid. The outcomes of RQ2 demonstrate the methods that students have described for fostering cooperation with Gen AI in their programming education. Self-evaluation and active use of AI, such as asking questions and paraphrasing answers when learning complex codes, were among the tactics mentioned by the students.

Students explained the approach by segmenting complex activities into digestible chunks and making incremental progress when working on app development projects. Additionally, they used conversations with Gen AI to obtain a variety of viewpoints that aided in work completion and problem solving. The findings of RQ3 highlighted the benefits of Gen AI for students' learning, including instant response access and nonjudgmental engagement, which have been shown in numerous other research [41–43]. More significantly, students' learning methods have changed from traditional sequential learning to simultaneous information input and output, which provides a hands-on experience in real time and produces deeper learning outcomes.

RQ4's findings highlight the challenges and individual variations in student-Gen AI cooperation on challenging

learning tasks.Students had trouble pointing out Gen AI's errors, clearing up misunderstandings, and working together to find answers in order to guarantee that their learning objectives were met. These issues demonstrated how difficult it is to establish equitable learning objectives and foster long-term student-Gen AI collaboration in order to accomplish challenging learning objectives. Therefore, additional empirical study is required to investigate how students might guide Gen AI to assist themselves through increasingly complex learning processes and how they can connect with Gen AI more fairly and efficiently.

Most importantly, this case study suggests that student-Gen AI collaboration can successfully enhance students' self-regulated and metacognitive learning abilities, which would help them avoid surface learning. Students with stronger metacognitive and self-regulated learning abilities may also be able to work with Gen AI more successfully. These kids are therefore expected to improve their capacity for self-regulated learning, grow into self-sufficient learners, and be able to continue learning with Gen AI without assistance from teachers. As a result, this study suggests that more work should be done to support students in maintaining a higher level of autonomy and leadership when interacting with Gen AI.

Limitations:

There were two restrictions on this case study. First and foremost, the generalizability of our findings is constrained by the small sample size of just nine individuals from the education department. Furthermore, the range of subjects in this study and the variation in instructors' teaching styles are expected to have an impact on the dynamics of student–Gen AI collaboration [28]. Notably, our study benefited from the teachers' substantial programming and Gen AI experience, which may not be typical.

Future Directions and Implications:

In contrast to earlier research, the student-AI interaction was prioritized, and students were told to work with Gen AI on learning tasks rather than merely utilizing it. Consequently, a number of conclusions could be drawn. The possibility that Gen AI will spread false or biased knowledge has drawn criticism [44]. Our results imply that students can lessen this risk by interacting with Gen AI from a variety of angles and carefully examining the information sources. Additionally, regular and purposeful engagement with Gen AI seems to improve students' interpersonal communication and critical thinking abilities. Furthermore, our study shows that student-Gen AI collaborations can improve students' metacognitive and self-regulated learning skills as well as deepen their engagement in the learning process, defying the fear of superficial learning or the absence of learning as a result of an overreliance on Gen AI.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] J.-H. Lee, D.-H. Kim, S.-N. Jeong, and S.-H. Choi, "Detection and diagnosis of dental caries using a deep learning-based convolutional neural network algorithm", J. Dent., Jul. 2018.

[2] R. Esmaeilyfard, H. Bonyadifard, and M. Paknahad, "Dental caries detection and classification in CBCT images using deep learning", Int. Dent. J., vol. 74, no. 2, pp. 328–334, Apr. 2024.

[3] M. T. G. Thanh, N. Van Toan, V. T. N. Ngoc, N. T. Tra, C. N. Giap, and D. M. Nguyen, 'Deep learning application in dental caries detection using intraoral photos taken by smartphones', Appl. Sci. (Basel), vol. 12, no. 11, p. 5504, May 2022.

[4] Askar, H.; Krois, J.; Rohrer, C.; Mertens, S.; Elhennawy, K.; Ottolenghi, L.; Mazur, M.; Paris, S.; Schwendicke, F. Detecting white spot lesions on dental photography using deep learning: A pilot study. J. Dent. 2021, 107, 103615.

[5] Mao, Q.-C.; Sun, H.-M.; Liu, Y.-B.; Jia, R.-S. Mini-YOLOv3: Real-time object detector for embedded applications. IEEE Access 2019, 7, 133529–133538.

[6] Cao, C.; Wang, B.; Zhang, W.; Zeng, X.; Yan, X.; Feng, Z.; Liu, Y.; Wu, Z. An improved faster R-CNN for small object detection. IEEE Access 2019, 7, 106838–106846.

[7] Thanh, M.T.G.; Van Toan, N.; Toan, D.T.T.; Thang, N.P.; Dong, N.Q.; Dung, N.T.; Hang, P.T.T.; Anh, L.Q.; Tra, N.T.; Ngoc, V.T.N. Diagnostic Value of Fluorescence Methods, Visual Inspection and Photographic Visual Examination in Initial Caries Lesion: A Systematic Review and Meta-Analysis. Dent. J. 2021, 9, 30.

[8] Van Gorp G, Maes A, Lambrechts M, Jacobs R, Declerck D. Is use of CBCT without proper training justified in paediatric dental traumatology? An exploratory study. BMC Oral Health. 2023;23(1):270. doi: 10.1186/s12903-023-03013-y.

[9] Park YS, Ahn JS, Kwon HB, Lee SP. Current status of dental caries diagnosis using cone beam computed tomography. Imaging Sci Dent. 2011;41(2):43–51. doi: 10.5624/isd.2011.41.2.43.

[10] Al-Rawi N, Sultan A, Rajai B, Shuaeeb H, Alnajjar M, Alketbi M, et al. The effectiveness of artificial intelligence in detection of oral cancer. Int Dent J. 2022;72(4):436–447. doi: 10.1016/j.identj.2022.03.001.

[11] Inês Meurer, M.; Caffery, L.J.; Bradford, N.K.; Smith, A.C. Accuracy of dental images for the diagnosis of dental caries and

enamel defects in children and adolescents: A systematic review. J. Telemed. Telecare 2015, 21, 449–458.

[12] Hung KF, Ai QYH, Wong LM, Yeung AWK, Li DTS, Leung YY. Current applications of deep learning and radiomics on CT and CBCT for maxillofacial diseases. Diagnostics. 2023;13(1):110.

[13] Lam DW, Chau DR. Biomimetic dental prostheses designed by artificial intelligence versus CAD software. Int Dent J. 2023;73::S32–S33. doi: 10.1016/j.identj.2023.07.298.

[14] Lee JH, Kim DH, Jeong SN, Choi SH. Detection and diagnosis of dental caries using a deep learning-based convolutional neural network algorithm. J Dent. 2018;77:106–111. doi: 10.1016/j.jdent.2018.07.015.

[15] Gao H, Xiao J, Yin Y, Liu T, Shi J. A mutually supervised graph attention network for few-shot segmentation: the perspective of fully utilizing limited samples. IEEE Trans Neural Netw Learn Syst. 2022:1–13. doi: 10.1109/TNNLS.2022.3155486.

[16] Sindhu, S.N., Prasad, R.S. (2024). Dental caries detection using Neural Turing Machines (NTM) and High Intensity Color Detection (NTM-HICD) model. Revue d'Intelligence Artificielle, Vol. 38, No. 2, pp. 671-679. https://doi.org/10.18280/ria.380231

[17] A. Imak, A. Celebi, K. Siddique, M. Turkoglu, A. Sengur and I. Salam, "Dental Caries Detection Using Score-Based Multi-Input Deep Convolutional Neural Network," in IEEE Access, vol. 10, pp. 18320-18329, 2022, doi: 10.1109/ACCESS.2022.3150358.

[18] P. Singh and P. Sehgal, "Automated caries detection based on radon transformation and DCT," in Proc. 8th Int. Conf. Comput., Commun. Netw. Technol. (ICCCNT), Jul. 2017, pp. 1–6, doi: 10.1109/ICCCNT.2017.8204030.

[19] Rasool Esmaeilyfard, Haniyeh Bonyadifard, and M. Paknahad, "Dental Caries Detection and Classification in CBCT Images Using Deep Learning," International Dental Journal, Nov. 2023, doi: https://doi.org/10.1016/j.identj.2023.10.003.

[20] K. Clark et al., "The Cancer Imaging Archive (TCIA): Maintaining and Operating a Public Information Repository," Journal of Digital Imaging, vol. 26, no. 6, pp. 1045–1057, Jul. 2013, doi: https://doi.org/10.1007/s10278-013-9622-7.